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Feasibility of unattended home polysomnography in children with sleep-disordered breathing

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ABSTRACT

Objective: To investigate the technical feasibility of unattended polysomnography (HPSG) for diagnosis of obstructive sleep apnea (OSA) in children.
Methods: A single-night HPSG was performed on children referred to the pediatric respiratory laboratory. Non-interpretable HPSGs were defined as: recordings with (i) loss of ≥2 of the following channels: nasal flow, or thoraco-abdominal belts, or (ii) HPSG with less than 4 h of artifact-free recording time or (iii) less than 4 h SpO2 signal.
Results: Of n = 101 included HPSGs, n = 75 were ambulatory and n = 26 in hospitalized subjects. Median (minimum–maximum) age was 2.8 (0–15.4) years. Interpretable and technically acceptable recordings were obtained in 94 subjects (93%). Only 7 recordings (4 at home versus 3 in hospitalized subjects, p-value = 0.254) were classified as non-interpretable and had to be repeated. Artifact-free recording time was 461 (23–766) min. Complete artifact-free pulse oximetry signal was obtained in 14% of the included subjects. Neither age, gender, AHI, nor place of performance was significantly associated with the interpretability of recordings.
Discussion: HPSG showed a high rate of interpretability and technical acceptance. The high technical feasibility obtained by HPSG may help to improve simple screening tests for OSA in children.

1. Introduction

Sleep-disordered breathing affects up to 10% of all children [1]. The disease spectrum ranges from apparently milder forms like primary snoring to more severe manifestations like obstructive sleep apnea (OSA) [2]. There is consistent evidence that even those apparently milder forms of SDB may lead to serious neurocognitive, behavioral [3–5] and cardiovascular consequences [6] in children. Considering the high prevalence of SDB and its serious consequences, early diagnosis seems to be mandatory.

Unfortunately, OSA cannot be diagnosed based only on clinical history or physical examination [7], being full-night sleep lab-based polysomnography the currently recommended gold standard for diagnosis [8]. Nevertheless, this test is expensive, time-consuming, and not always available in the clinical setting [9]. These shortcomings have led to the search of new non-invasive, cheaper and highly available possibilities for diagnosing OSA. However, a recent systematic review conducted by our group showed failures in several widely used tests for diagnosing OSA in children [10]. Among the few tests that demonstrated relevant diagnostic accuracies, unattended portable polysomnography (HPSG) showed promising results [10]. Use of small portable devices at home spares costs, hospital stays, and may even improve sleep quality of the children undergoing the evaluation [11]. In contrast to studies involving adults, there have been only few studies that researched the use of HPSG in children [9,11–14]. Notwithstanding the small number of published studies, reference values for HPSG are available [12].

The feasibility of HPSG on snoring children has been only investigated in one of the above-mentioned studies on children [9]. Moreover, there is still lack of an analysis of factors that may influence the feasibility of non-attended HPSG. Therefore, the aim of the present study was to investigate the technical feasibility of unattended HPSG using portable equipment.

2. Methods

2.1. Subjects

Recordings from HPSG performed on children referred to the Pediatric Respiratory Laboratory between 2010 and 2011 were included. All performed consecutive recordings during this period

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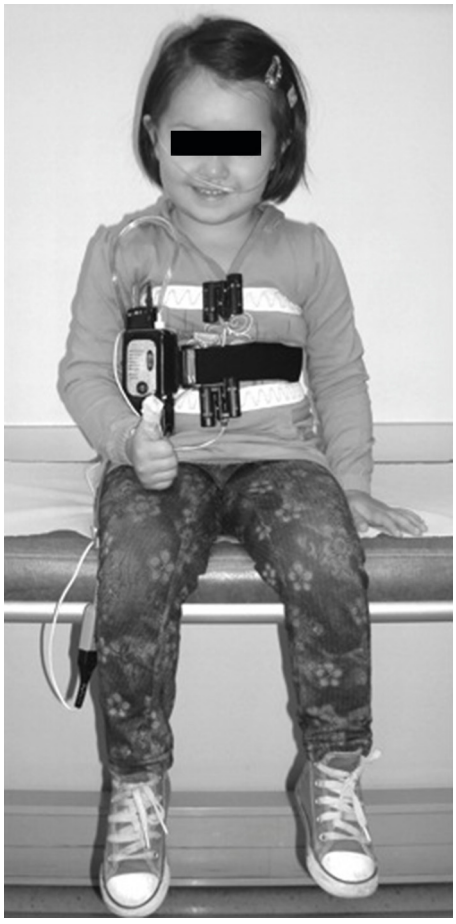

Fig. 1. A 4-year-old girl with the portable polysomnographic equipment used in the study. Taken with the kind permission of the girl and her parents.

were included. There were no excluded recordings. All included children were Hispanic and referred for HPSG due to habitual snoring (i.e., snoring for more than 3 nights a week) or the suspicion of having apneas. The study was approved by the Ethics Committee of the Faculty of Medicine at the Pontificia Universidad Católica in Santiago de Chile (Approval number 13-022).

2.2. Procedures

HPSG was performed on all children using a portable cardiorespiratory device (Embletta® Gold™III, Embla, Broomfield, Colorado, USA). The following six channels were recorded: (i) nasal flow using a pressure transducer cannula, (ii) thoracic and (iii) abdominal movements, (iv) pulse oximetry, (v) heart rate measured by electrocardiography, and (vi) position sensor. A trained nurse explained the procedure to parents or caregivers. Fig. 1 shows a subject with the portable equipment and the study setting. The device used for the HPSG was installed during the evening in the lab and returned by the parents of the children the next morning. Parents were taught how to check if sensors were placed adequately and put in charge of checking the correct position of the nasal cannula, thoracic and abdominal belts and the sensor of the pulse oximetry. A hotline number was given to parents in order to answer questions or solve problems.

In the case of hospitalized patients, a trained nurse installed the HPSG device. All hospitalized and ambulatory subjects were attended by the same nurse. This nurse asked parents about complaints or difficulties in relation to the use of the equipment. The procedure was explained to night shift nursing staff. The same above-mentioned hotline was also available for hospital nursing staff. Data collected by the device was downloaded the morning after the recording and interpreted by a trained sleep specialist according to current guidelines. Artifacts were defined as the loss of signals in nasal pressure, thoracic and abdominal movements, pulse oximetry, and heart rate. Total recording and artifact times were registered in each subject. Artifact-free recording time was obtained by resting artifact time from total recording time. At least 4 h of artifact-free recording time were required as minimum for interpretation. Respiratory events and sleep architecture were analyzed according to the current guidelines [15]. Central apneas were defined as the absence of nasal airflow and thoraco-abdominal movements of at least 20 s, or for at least two breaths when accompanied by a decrease in SpO2 of >3%. Obstructive apneas were defined as the absence of airflow with continued chest wall and abdominal movement for the duration of at least 2 breaths. Obstructive apneas did not require an associated desaturation event in order to be accepted [15]. The absence of signal in the snoring channel and the presence of paradoxical respiratory movements were used in order to differentiate apneas from possible artifacts. Hypopneas were defined as a decrease in nasal flow of at least 50% with a corresponding decrease in SpO2 of 3% or more (18). Fig. 2 shows scoring examples. We also defined flow limitations as the decrease in nasal flow by <30% without a decrease in SpO2. The apnea–hypopnea index (AHI) was defined as the number of central, obstructive apneas and hypopneas per hour of artifact-free recording time. The mixed obstructive apnea hypopnea index (MOAHI) was calculated by summing only obstructive and mixed apneas and hypopneas per hour of

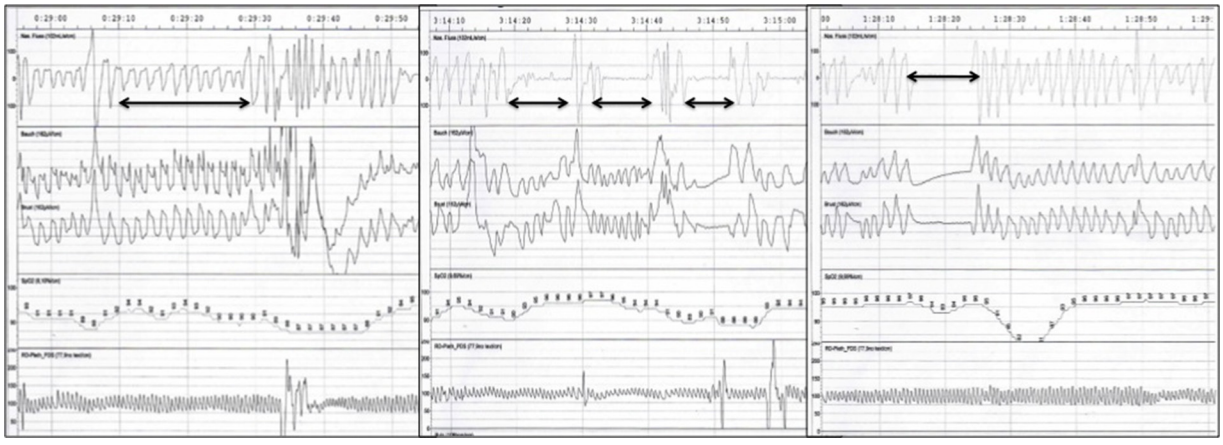

Fig. 2. Scoring examples. Arrows show the respiratory events. Left: hypopnea, center: two obstructive and one mixed apnea, right: central apnea.

Table 1
Demographic and polysomnographic results of the sample.

	Total sample (n = 101)	At home (n = 75)	Hospitalized (n = 26)	p-Value
Age (years)	2.8 (0–15.4)	3.8 (0–15)	0.3 (0–15.4)	0.001
Males, n (%)	47 (47)	39 (52)	8 (31)	0.071
Total recording time (min)	720 (480–1440)	511 (23–720)	541 (102–1080)	0.199
Artifact time (min)	12 (0–922)	7 (0–463)	50 (2–922)	0.001
Artifact-free recording time (min)	461 (23–766)	483 (23–720)	455 (100–766)	0.513
AHI (events/h)	0.8 (0–46)	0.6 (0–24)	1.1 (0–46)	0.024
Mean SpO2	96.4 (76–100)	96.9 (76–99)	95.4 (89–100)	0.003
Test non-interpretable, n (%)	7	4	3	0.254

Abbreviations: AHI, apnea-hypopnea index; n, number; SpO2, pulse oximetry derived oxygen saturation. If not otherwise stated, all results are given as medians (minimum–maximum) for not normally distributed variables.

artifact-free recording time The respiratory disturbance index was calculated by summing all central, obstructive and mixed apneas, hypopneas and flow limitations per hour of artifact-free recording time. OSA was defined as an MOAHI ≥ 1. An upper airway resistance syndrome was defined as an RDI ≥ 1 and AHI < 1. Primary snorers had an RDI and AHI < 1.

2.3. Evaluation of feasibility

Feasibility was assessed in terms of need for a new recording due to non-interpretability. Non-interpretable HPSGs were defined as: recordings with (i) loss of $\geq$2 of the following channels: nasal flow, or thoraco-abdominal belts, or (ii) HPSG with less than 4 h of artifact-free recording time or (iii) less than 4 hours SpO2 signal. Recordings that met one or more of the above-mentioned criteria were considered to be non-interpretable and thus requiring repetition.

2.4. Statistics

Descriptive statistics (numbers, percentages, and median, minimum, maximum for not normally distributed variables) were used to summarize children's demographic characteristics and the loss of each signal. In order to investigate the factors that may influence the interpretability of the recordings made by the portable polysomnographic device, a logistic regression was conducted. Age, gender, AHI, and place of the recording (home versus hospital) were analyzed as independent variables in this logistic regression equation. Odds ratios and their 95% confidence intervals were calculated. All analyses were done with statistical software SPSS 20.0 (Statistical Package for the Social Science 20.0 for Mac). A p-value < 0.05 was considered statistically significant.

3. Results

Recordings from n = 101 children (males n = 47; 46.5%) were included. Demographic and HPSG variables were distributed not normally. Median (minimum–maximum) age was 2.8 (0–15.4) years. Of all analyzed HPSGs, n = 75 were ambulatory and n = 26 performed on hospitalized children. The most frequent diagnoses were: primary snorer (n = 33), normal (n = 24), OSA (n = 19), upper-airway resistance syndrome (n = 12), frequent desaturations (n = 7), and central apneas (n = 6). Median (minimum–maximum) AHI was 0.8 (0–46), respiratory disturbance index was 1.4 (0–65.4). The same figure for mean SpO2 was 96.4% (76–100%). One subject had a stable congenital cyanotic heart condition that explained the minimum SpO2 of 76% mentioned above. Hospitalized subjects were younger than subjects in the HPSG group (3.8 versus 0.3 years; respectively, p-value = 0.001) and showed a tendency toward higher AHI (0.6 versus 1.1; respectively, p-value = 0.024). Demographic characteristics and polysomnographic indices of the included subjects are given in Table 1.

Table 2
Absence of artifacts in the recorded channels.

Channel without artifacts in n (%)	Total sample (n = 101)
Nasal flow	70 (70)
Thoracic movement	47 (47)
Abdominal movement	55 (55)
SpO2	14 (14)
Pulse	15 (15)
Snoring	99 (98)

Abbreviations: n, number; SpO2, pulse oximetry derived oxygen saturation.

Table 3
Analysis of predictors of non-interpretability.

	Odds ratio	95% CI	p-Value
Gender	5.938	0.604–58.388	0.127
Age	1.003	0.985–1.022	0.756
Place of HPSG	1.212	0.178–8.262	0.845
AHI	0.947	0.854–1.050	0.302

Dependent variable was the non-interpretability of the study defined as: recordings with (i) loss of $\geq$2 of the following channels: nasal flow, or thoraco-abdominal belts, or (ii) HPSG with less than 4 h of artifact-free recording time or (iii) less than 4 h SpO2 signal. Abbreviations: AHI, apnea hypopnea index; CI, confidence interval; HPSG, unattended portable polysomnography.

Parents referred no complaints concerning the use of the portable equipment. There were 3 calls to the hotline, in all of them parents asked about how to reinsert a cable to the portable device. In n = 7 cases (7% of the total) there was a need for repetition of the test due to signal failure according to the above-mentioned definitions. Of those cases, n = 4 were HPSG and n = 3 hospitalized subjects. Median (minimum–maximum) age of these subjects was 0.3 (0–13.8) years, 6 out of 7 were males. In the remaining n = 94 subjects (93%), the test was interpretable according to the above-mentioned definition and the recording results were technically acceptable.

Median (minimum–maximum) total recording time was 720 (480–1440) min. The same figure for artifact-free recording time was 461 (23–766) min. Table 2 gives the number and percentages of the recording with the absence of artifacts in each analyzed channel. Logistic regression showed that age, gender and place of recording (home versus hospital) were no significant predictors for interpretability of the recording or for signal failure (Table 3).

4. Discussion

The present study showed that a simple and portable home recording method for OSA is possible and technically feasible on children independent of their age or gender. Moreover, unattended home recordings seem to perform as well as supervised in-hospital measurements. There were a high number of interpretable recordings in this sample of high-risk children.

Full-night sleep lab-based polysomnography is considered the gold standard for diagnosing OSA in children [8]. This method has undeniable advantages: it provides standard indices like the AHI, gives a severity level of OSA, and shows highly valuable parameters like arousal index or sleep stage distribution. However, this gold standard is not always available for the approximately 10% of children that are estimated to snore [16]. On the other hand, there is evidence that questionnaires and physical examination do not predict OSA in children [10]. Recently, Spruyt et al. analyzed the validity of the set of six questions for screening of children at high risk for SDB [17]. Although there were promising results that the study stated that questionnaires could not be used as the sole diagnostic approach for OSA in children [17]. HPSG may be an option to complement the information of questionnaires. In an interesting study on the diagnostic usefulness of questionnaires, Villa et al. showed that a sleep score correlated well with the AHI [18]. The combination of questionnaires and the information of HPSG may be of interest in future studies. On the other hand, the use of HPSG devices may be a cheaper form to perform population-based OSA screenings.

In adults, there is consistent evidence that AHI and other indices obtained from portable unattended polysomnographic devices correlate excellently with standard lab-based polysomnography [19–21]. Overall, there was a good to excellent diagnostic test accuracy when comparing home or portable polysomnographic devices with full sleep lab-based polysomnography [19–21]. In one of these studies on 55 adults, one half of them were randomly assigned to be receive a technician supervised set up of HPSG, and the other half conducted their own setup of HPSG [22]. There were more non-interpretable results in the latter: 7% of the attended versus 33% of unattended tests failed because of artifacts [22]. In the present study, parents were instructed how to handle a simple portable device at home. In the majority of unattended recordings in the present study (i.e., 95% of all HPSG) an interpretation was possible according to our definitions.

In contrast to adult-based studies, there are few studies that aimed to compare the diagnostic usefulness of portable devices for diagnosing OSA in children [11,13,23]. Zucconi et al. studied the usefulness of portable equipment in 12 children aged 3–6 years [23]. A high correlation between the respiratory disturbance index obtained by the portable device and full polysomnography was achieved. However, both tests were performed in the sleep lab [23]. Analysis of the usefulness of unattended HPSG was conducted by Jacob et al. [11]. In 21 children aged 2–12 years HPSG and full sleep lab polysomnography were compared. There were no significant differences in the AHI, apnea and desaturation indices between both tests. Furthermore, higher sleep efficiency was described in the HPSG group [11]. In the largest study on portable polysomnographic devices so far, Alonso-Alvarez et al. [13] investigated the diagnostic usefulness of portable equipment for diagnosing OSA in 53 children aged 2–13 years. Measurements with portable equipment as well as a full sleep lab-based polysomnography were recorded simultaneously. There was an excellent correlation between the indices obtained with both tests. The usefulness of portable polysomnographic equipment for diagnosing OSA seems to be of a great value for children with OSA. However, the three existing studies that compared measurements with such simplified portable systems to full polysomnography tests had some limitations. First, only thermistors were used, not the currently recommended nasal pressure transducers. Second, Jacob's study from 1995 investigating the validity of unattended home polysomnography included only a relatively small sample of children [11]. Although this study reported an 83% success rate, no information was provided on what was considered a successful or interpretable study.

Feasibility in terms of non-interpretable results and artifacts remained unanswered in the above-mentioned studies. Literature on feasibility of HPSG on children is also very sparse. In one study on 132 subjects Sardon-Prado et al. compared HPSG to recordings performed with a portable device on hospitalized children [14]. No significant differences were found between the interpretability of HPSG and in-hospital polysomnography [14]. Subjects included in that study were older than the children who participated in the present study (average age of 8.3 versus 2.8 years). Interestingly, we were able to demonstrate a high ratio of interpretable HPSG in preschool children, which is comparable to that reported by Sardon-Prado's study in much older subjects [14]. In another study on feasibility of HPSG in children, Poels et al. [9] obtained technically acceptable recordings in 18 out of 24 children (75%). In that study, a signal analysis was conducted, showing that the highest rate of failure was found in the signal of the nasal cannula [9]. In the present study, the highest signal failure was found in the SpO2 registries.

Interestingly, the place of performance was not significantly associated with uninterpretability. One may have assumed that a supervised environment, with nursing staff and availability of all in-patient resources would improve the interpretability of the test. However, the presence of nursing staff did not seem to have improved the quality of the in-hospital recordings versus those taken at home. We were not able to compare at home and hospitalized HPSG, due to the small sample size and different demographic factors between the above-mentioned groups. On the other hand, neither age, gender nor AHI was significant factors associated with the failure of the recordings.

Among the limitations of the present study, the lack of comparison with a full sleep lab-based polysomnography deserves some explanation. We agree that the comparison between a novel diagnostic test and the current recommended gold standard (i.e., full sleep lab-based polysomnography) is surely necessary for a validity study. However, a validation of HPSG was not the objective of this study. We aimed to compare the interpretability of a simple portable polysomnographic device in two settings: at home and in-hospital. The good feasibility measured by our study may hopefully lead to future studies that assess the diagnostic test validity of HPSG. On the other hand, comparison of feasibility with previous studies was difficult as there are few existing studies on this topic involving children [9,14]. In the present study, all children were Hispanic and we did not assessed socioeconomic status. Furthermore, definitions of interpretability of the recordings and the required minimum duration of artifact-free recording time vary greatly [9]. We defined interpretability rather strictly based on a requirement of 4 h of artifact-free recording time and the existence of nasal, thoraco-abdominal, and SpO2 signal, according to reference values previously recommended by Moss et al. [12]. This definition is not as strict as the minimum of 390 min artifact-free recording time in Poels study. On the other hand, the present study involved children who were younger than those included in previously published feasibility studies [9,14]. Furthermore, the software used in one of these previous studies [9] was not able to discard manually rejected parts of the test. Another limitation of the present study is that we did not record electroencephalography (EEG) during HPSG. In some cases the use of EEG adds to the identification of possible events and a proper sleep staging. The sudden changes in sleep EEG activity are defined as arousals according to current guidelines [24,25] are extremely frequent phenomena in children with SDB and are thought to be rather a protective mechanism for re-establishing breathing and avoid the collapse of the upper airway [26]. How the identification of EEG based arousal would have changed the diagnosis is also unclear. However, as definition of obstructive apneas do not need the association with arousal or desaturation [15] we hypothesize that this may not have affected proper diagnosis in this population.

Also, we did not measure CO2 using capnography. Therefore, there might have been some children with hypercarbia that were not identified. As portable devices are developing new technologies incorporating EEG and canography, we encourage future studies to analyze also the feasibility using these signals in HPSG.

5. Conclusions

To our knowledge, the present study represents the first attempt to analyze the feasibility of using portable unattended HPSG devices in toddlers and preschool children, and to compare it with the results of the same procedure used on hospitalized subjects. The high rate of interpretability may help to develop prospective population based screening studies that compare the diagnostic accuracy of cheaper and simpler technologies for screening OSA in children.

Conflicts of interest

The authors have no conflicts of interest to declare. No funding was associated with the present study.

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References

[1] J.C. Lumeng, R.D. Chervin, Epidemiology of pediatric obstructive sleep apnea, Proc. Am. Thorac. Soc. 5 (2) (2008) 242–252.
[2] C.L. Marcus, Sleep-disordered breathing in children, Am. J. Respir. Crit. Care Med. 164 (1) (2001) 16–30.
[3] P.E. Brockmann, P. Bertrand, T. Pardo, J. Cerda, B. Reyes, N.L. Holmgren, Prevalence of habitual snoring and associated neurocognitive consequences among Chilean school aged children, Int. J. Pediatr. Otorhinolaryngol. 76 (9) (2012) 1327–1331.
[4] L.M. O'Brien, C.B. Mervis, C.R. Holbrook, J.L. Bruner, C.J. Klaus, J. Rutherford, et al., Neurobehavioral implications of habitual snoring in children, Pediatrics 114 (1) (2004) 44–49.
[5] D.W. Beebe, Neurobehavioral morbidity associated with disordered breathing during sleep in children: a comprehensive review, Sleep 29 (9) (2006) 1115–1134.
[6] R. Bhattacharjee, J. Kim, W.H. Alotaibi, L. Kheirandish-Gozal, O.S. Capdevila, D. Gozal, Endothelial dysfunction in children without hypertension: potential contributions of obesity and obstructive sleep apnea, Chest 141 (3) (2012) 682–691.
[7] M.S. Schechter, Technical report: diagnosis and management of childhood obstructive sleep apnea syndrome, Pediatrics 109 (4) (2002) 20.
[8] C.L. Marcus, L.J. Brooks, K.A. Draper, D. Gozal, A.C. Halbower, J. Jones, et al., Diagnosis and management of childhood obstructive sleep apnea syndrome, Pediatrics 130 (3) (2012) 576–584.
[9] P.J.P. Poels, A.G.M. Schilder, A.W. Hoes, K.F.M. Joosten, Evaluation of a new device for home cardiorespiratory recording in children, Arch. Otolaryngol. Head Neck Surg. 129 (12) (2003) 1281–1284.
[10] P.E. Brockmann, C. Schaefer, A. Poets, C.F. Poets, M.S. Urschitz, Diagnosis of obstructive sleep apnea in children: a systematic review, Sleep Med. Rev. 17 (5) (2012) 331–340.
[11] S.V. Jacob, A. Morielli, M.A. Mograss, F.M. Ducharme, M.D. Schloss, R.T. Brouillette, Home testing for pediatric obstructive sleep apnea syndrome secondary to adenotonsillar hypertrophy, Pediatr. Pulmonol. 20 (4) (1995) 241–252.
[12] D. Moss, M.S. Urschitz, A. von Bodman, S. Eitner, A. Noehren, P.M. Urschitz-Duprat, et al., Reference values for nocturnal home polysomnography in primary school children, Pediatr. Res. 58 (5) (2005) 958–965.
[13] M.L. Alonso Alvarez, J. Teran Santos, J.A. Cordero Guevara, A.I. Navazo Eguia, E. Ordax Carbajo, J.F. Masa Jimenez, et al., [Reliability of respiratory polygraphy for the diagnosis of sleep apnea-hypopnea syndrome in children], Arch. Bronconeumol. 44 (6) (2008) 318–323.
[14] O.F.G. Sardon, A. Aldasoro, M. Estévez, J. Mintegui, J. Korta, J.I. Emparanza, Diagnostic utility of nocturnal in-home respiratory polygraphy, An. Pediatr. (Barc.) 65 (4) (2006) 310–315.
[15] C. Iber, S. Ancoli-Israel, A. Chesson, S. Quan, The AASM Manual for the Scoring of Sleep and Associated Events: Rules, Terminology, and Technical Specifications, Ill American Academy of Sleep Medicine, Westchester, 2007.
[16] M.S. Urschitz, P.E. Brockmann, M. Schlaud, C.F. Poets, Population prevalence of obstructive sleep apnoea in a community of German third graders, Eur. Respir. J. (2010) (in press).
[17] K. Spruyt, D. Gozal, Screening of pediatric sleep disordered breathing: a proposed unbiased discriminative set of questions using clinical severity scales, Chest 142 (6) (2012) 1508–1515.
[18] M.P. Villa, M.C. Paolino, R. Castaldo, N. Vanacore, A. Rizzoli, S. Miano, et al., Sleep clinical record: an aid to rapid and accurate diagnosis of paediatric sleep disordered breathing, Eur. Respir. J. 41 (6) (2013) 1355–1361.
[19] F. Portier, A. Portmann, P. Czernichow, L. Vascaut, E. Devin, D. Benhamou, et al., Evaluation of home versus laboratory polysomnography in the diagnosis of sleep apnea syndrome, Am. J. Respir. Crit. Care Med. 162 (3 Pt 1) (2000) 814–818.
[20] S. Esnaola, J. Duran, C. Infante-Rivard, R. Rubio, A. Fernandez, Diagnostic accuracy of a portable recording device (MESAM IV) in suspected obstructive sleep apnoea, Eur. Respir. J. 9 (12) (1996) 2597–2605.
[21] S. Redline, T. Tosteson, M.A. Boucher, R.P. Millman, Measurement of sleep-related breathing disturbances in epidemiologic studies. Assessment of the validity and reproducibility of a portable monitoring device, Chest 100 (5) (1991) 1281–1286.
[22] R. Golpe, A. Jimenez, R. Carpizo, Home sleep studies in the assessment of sleep apnea/hypopnea syndrome, Chest 122 (4) (2002) 1156–1161.
[23] M. Zucconi, G. Calori, V. Castronovo, L. Ferini-Strambi, Respiratory monitoring by means of an unattended device in children with suspected uncomplicated obstructive sleep apnea: a validation study, Chest 124 (2) (2003) 602–607.
[24] M.C. Lopes, C.L. Marcus, The significance of ASDA arousals in children, Sleep Med. 9 (1) (2007) 3–8.
[25] EEG arousals: scoring rules and examples: a preliminary report from the Sleep Disorders Atlas Task Force of the American Sleep Disorders Association. Sleep 15(2) (1992) 173–184.
[26] M.C. Lopes, C. Guilleminault, Chronic snoring and sleep in children: a demonstration of sleep disruption, Pediatrics 118 (3) (2006) e741–e746.